

GAO
Report to the Chairman, Subcommittees
on Defense, Senate and House
Committees on Appropriations

ARMY PROCUREMENT

Costs and Benefits of Electronic and Mechanical Time Pieces



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National Security and
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B-235416

December 22, 1989

The Honorable Daniel K. Inouye
Chairman, Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable John P. Murtha
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

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As requested in the Conference Committee report on Department of Defense appropriations for fiscal year 1989 and as agreed in subsequent discussions with your offices, we reviewed data supporting the Army's decision to type classify¹ the M762 electronic time fuze and the costs and benefits of the electronic time fuze as compared to the costs and benefits of the existing mechanical time fuze. We also reviewed the Army's fiscal year 1990 budget request for electronic time fuzes.

In May 1989, we reported on the type classification of the M762 electronic time fuze, and in October 1989, we reported on the results of our evaluation of the Army's fiscal year 1990 budget request for electronic time fuzes.² In this report, we are providing the results of our review of the costs and benefits of the fuzes. The results are summarized in this letter and discussed more fully in appendixes I, II, and III. Our objectives, scope, and methodology are discussed in appendix IV.

Results in Brief

The M762 electronic time fuze and the M577 mechanical time fuze are both capable of satisfying the Army's current requirement for artillery time fuzes. The electronic time fuze has two operational advantages over the mechanical time fuze: (1) it can be set both manually and automatically, and (2) it can be set manually without the use of a tool.

During the first 3 years of its production, the M762 fuze will cost more than the M577 mechanical fuze. Also, its most important advantage, the autotest capability, cannot be utilized now because existing and near-

¹When an item is type classified as standard it is identified as acceptable for its intended mission and for introduction into the inventory.

²Army Ammunition: Acquisition of the M762 Electronic Time Fuze and the XM900E1 Tank Round (GAO/NSIAD-89-161, May 31, 1989) and Defense Budget: Potential Reductions to DOD's Fiscal Year 1990 Ammunition Budget (GAO/NSIAD-90-23, Oct. 23, 1989).

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future artillery systems are not designed to use a fuze that can be set automatically from a remote location.

The M577 mechanical time fuze fully meets the requirements of current and near-future artillery weapon systems. It is economical to procure, has a safe and reliable record, and can be produced by the current manufacturer in higher quantities than the Army's stated annual requirements.

The Army's stated requirement for artillery time fuzes for fiscal year 1990 can be met with mechanical time fuzes for considerably less than the \$54.9 million contained in its fiscal year 1990 budget request for the procurement of electronic time fuzes. We estimated that the requirement could have been met with the \$23.2 million already appropriated for the procurement of electronic time fuzes in fiscal year 1989.

We briefed your Subcommittee staffs on our findings in July 1989 and told them that we believed that the Army's request for \$54.9 million for electronic fuzes in fiscal year 1990 was not fully justified. On November 13, 1989, the Conference Committee on Department of Defense appropriations for fiscal year 1990 provided \$40 million to procure electronic time fuzes in fiscal year 1990. In providing the funds, the Conference Committee stated that the Army should use fiscal year 1989 and 1990 funds to procure a sufficient number of electronic time fuzes to validate the technical data package and to demonstrate that these fuzes can be produced with sufficient quality at prices that are competitive with those of the current mechanical time fuzes. The report also stated that it is the intention of the conferees that deliveries of mechanical time fuzes will continue until a final decision is made on the further production of electronic time fuzes.

Background

The M577 mechanical time fuze is the current fuze used with all existing projectiles in the 105-mm, 155-mm, and 8-inch artillery weapon systems. The fuze contains a mechanical clockwork timing mechanism that can be set to function for 2 to 200 seconds. The fuze is set with a fuze setter or screwdriver. The setting key is at the nose of the fuze, and the time to be set is viewed on three dials through a window in the side of the curved nose. This fuze has been in use for many years.

According to the Army, the M762 electronic time fuze was developed to fill the need for an accurate, reliable, mass-producible, and low-cost electronic time fuze to use with current and developmental field artillery

weapon systems. The Army wanted a fuze that could be easily set by hand—requiring no tools. It also wanted a fuze that could be set automatically from a remote location, thereby permitting advanced artillery systems to achieve higher firing rates in a shorter response time. Like the M577 mechanical time fuze, the M762 electronic time fuze will be used with all existing and developmental projectiles in the 105-mm, 155-mm, and 8-inch artillery weapon systems.

Cost Concerns

The anticipated cost of the M762 electronic time fuze is considerably higher than the most recent cost of the M577 mechanical fuze. The Army attributes the higher unit cost for the electronic fuze to the need for the contractor to amortize its cost for producing the new fuze. The Army believes that the unit cost for the electronic fuze will be comparable to the unit cost for the mechanical fuze after the production of one million electronic fuzes or 3 years of production.

For fiscal year 1989, the Army had planned to procure 161,000 M762 electronic time fuzes—50,000 by a sole-source contract and 111,000 competitively from two producers. It now plans to procure the entire quantity competitively.

The Army estimated the initial unit procurement cost of the M762 electronic time fuze at \$127.88 in its fiscal year 1989 budget and at \$106.46 in its fiscal year 1990 budget request. After submitting its budgets for fiscal years 1989 and 1990, however, the Army received a negotiated unit price bid from the developer of the fuze for the initial procurement quantity of 50,000 electronic time fuzes for fiscal year 1989 that was substantially higher than the Army's estimate. The Army was unsuccessful in its attempts to negotiate a lower price with the developer. Therefore, it changed its acquisition strategy for the electronic fuzes from sole source for a limited quantity to fully competitive for the entire fiscal year 1989 requirement.

The Army received eight best and final bids for the 111,000 electronic fuzes that were to be procured competitively for fiscal year 1989. The lowest bids reflected unit prices that were considerably lower than the unit price bid by the developer but were significantly higher than the contract unit prices for the mechanical time fuze. We cannot disclose the actual bid prices because they are contract-sensitive.

In May 1989, the Army awarded a contract for about \$16 million for the purchase of 414,812 M577 mechanical time fuzes, or a unit price of

\$38.59. Since the Army had planned to procure only 207,000 mechanical and 161,000 electronic fuzes in fiscal year 1989, the actual procurement quantity of mechanical fuzes exceeded the Army's total artillery time fuze requirement for fiscal year 1989. Therefore, the Army does not need to procure any additional artillery time fuzes for fiscal year 1989. The funding provided for electronic time fuzes in fiscal year 1989 could be used to meet fiscal year 1990 requirements.

The Major Benefit of the Electronic Fuze Will Not Be Realized

The Army has identified several benefits of the M762 electronic time fuze over the M577 mechanical time fuze. The two major benefits are that (1) the electronic time fuze can be set automatically from a remote location and (2) it can be set manually without the aid of a tool. However, the first benefit will not be realized because current and near-future artillery systems are not configured to make use of a fuze that can be set from a remote location.

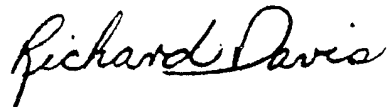
One of the existing artillery weapon systems is currently being improved under a modification program. At the onset of the modification program, the Army had planned to install an autosest capability in that artillery weapon system. However, the requirement for an autosest capability was subsequently eliminated from the program.

The Army plans to field an Advanced Field Artillery System, which is still under development. However, when requested, the Army did not provide documents showing that an autosest capability would be a part of this system. An Army official said that the requirement for an autosest capability is an implied requirement. We believe that without documentation for the requirement, there is no assurance that the Army has made a commitment to develop an artillery system that can use the automatic fuze-setting capability.

As requested, we did not obtain agency comments on this report. However, we discussed the results of our work with Office of the Secretary of Defense and Army officials and have included their comments where appropriate.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report for 30 days. At that time, we will send copies to the Secretaries of Defense and the Army; the Director, Office of Management and Budget; and other interested parties.

Please contact me at (202) 275-4141 if you or your staff have any questions concerning this report. Other GAO staff members who made major contributions to this report are listed in appendix V.

A handwritten signature in cursive script that reads "Richard Davis".

Richard Davis
Director, Army Issues

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Abbreviations

AMSAA	Army Materiel Systems Analysis Activity
GAO	General Accounting Office
NATO	North Atlantic Treaty Organization

Electronic and Mechanical Time Fuze Costs

For fiscal year 1989, the Army received \$15.9 million for the procurement of 207,000 mechanical time fuzes and \$23.2 million for the procurement of 161,000 M762 electronic time fuzes—a total of \$39.1 million for 368,000 fuzes. On May 2, 1989, the Army awarded a contract for about \$16 million to Bulova Systems and Instruments Corporation for 414,812 M577 mechanical time fuzes, or a unit price of \$38.59. This contract contains an option for the procurement of additional M577 mechanical time fuzes at a unit cost of \$54.32 for quantities in excess of 400,000 fuzes.

Since the 414,812 mechanical time fuzes contracted for procurement in fiscal year 1989 exceeded the Army's stated 1989 fuze requirement of 368,000 by 46,812 fuzes, the Army does not need to procure additional artillery time fuzes for fiscal year 1989 and could apply the 46,812 fuzes against its fiscal year 1990 fuze requirement.

The Army had planned to procure 161,000 M762 electronic time fuzes for fiscal year 1989: 50,000 fuzes were to be procured by a sole-source contract with the fuze developer—Motorola, Inc.—and 111,000 fuzes were to be procured competitively from two producers. However, the fuze developer's negotiated unit price bid for the initial 50,000 fuzes was substantially higher than the Army's estimate, and the Army was unsuccessful in its attempts to negotiate a lower price. Therefore, the Army decided to compete the entire initial procurement quantity of 161,000 fuzes planned for the fiscal year 1989 program. On November 27, 1989, the Army awarded a contract for the procurement of the electronic fuzes.

In its fiscal year 1989 budget submission, the Army estimated the unit cost for the initial quantity of M762 electronic time fuzes at \$127.88. In its budget submission for fiscal years 1990 and 1991, it estimated the unit costs for 417,120 M762 electronic fuzes in fiscal year 1990 at \$106.46 and for 324,000 fuzes in fiscal year 1991 at \$82.90.

By August 1989, the Army had received best and final offers from eight bidders for the fiscal year 1989 contract to manufacture M762 electronic time fuzes. The actual bid prices are contract-sensitive. However, we determined that, although the lowest bid prices were lower than the developer's unit price bid, they were considerably higher than the current unit price for M577 mechanical time fuzes. This is not unusual because initial production of a new item is typically more costly than production of a mature system.

The Army believes that the M762 unit cost will be comparable to the cost of the M577 mechanical time fuze by the third year of production or after one million electronic fuzes are produced. However, as stated in our October 1989 report on the Department of Defense's fiscal year 1990 ammunition budget, on the basis of current pricing information, we believe that substantial savings could be achieved if the Army were to continue to procure mechanical fuzes for existing and near-future artillery weapon systems.

In its fiscal year 1990 budget, the Army requested \$54.9 million for the procurement of 478,000 electronic time fuzes and no funds for the procurement of mechanical time fuzes. We concluded that if the \$23.2 million provided for procuring electronic fuzes in fiscal year 1989 were used to procure additional mechanical fuzes, the fiscal year 1990 request for electronic fuzes would not be needed.

The Conference Committee on Department of Defense appropriations for fiscal year 1990 provided \$40 million to procure electronic time fuzes in fiscal year 1990. In providing the funds, the Conference Committee report (House Report 101-345, Nov. 13, 1989) stated that the Army should use fiscal year 1989 and 1990 funds to procure a sufficient number of electronic time fuzes to validate the technical data package and to demonstrate that these fuzes can be produced with sufficient quality at prices that are competitive with those of the current mechanical time fuzes. The report also stated that it is the intention of the conferees that deliveries of mechanical time fuzes will continue until a final decision is made on the further production of electronic time fuzes.

Advantages and Disadvantages of the Electronic and Mechanical Fuzes

In response to questions during April 1988 hearings on the Army's fiscal year 1989 ammunition budget, the Army told the House Committee on Appropriations that electronic time fuzes will provide the following benefits over mechanical time fuzes:

- They can be set either automatically from a remote location or manually without the use of a tool.
- The production base for the electronic fuze will be larger.
- The fuzes will be compatible with North Atlantic Treaty Organization (NATO) artillery systems.
- The fuzes represent state-of-the-art technology.

The only disadvantage the Army cited for the electronic fuzes is that they will initially cost more to produce.

The Army cited two advantages of mechanical time fuzes: (1) they are currently in production, and (2) they can be currently procured at a lower unit price. The Army cited two disadvantages: (1) a tool is required to set them, and (2) they have a limited production base (few contractors compete to produce them).

Automatic Setting or Manual Setting Without the Use of a Tool

The Army said that the M762 can be set either automatically from a remote location or manually without the use of a tool. The M577 mechanical time fuze requires a setting tool or flat screwdriver. However, the autoset capability on the M762 cannot be realized until the Army has an artillery system that has an autoset capability. We noted that an autoset capability was planned for the 155-mm howitzer as part of the howitzer improvement program. However, the Army dropped the requirement for this capability 3 years ago.

Army officials stated that the autoset capability is required for future cannon artillery systems equipped with automatic loaders. However, the Army has made no commitment to developing artillery having an automatic fuze-setting capability. An Army official said that the requirement for an autoset capability is an implied requirement because the Army's new Advanced Field Artillery System requires a rate of fire of six rounds per minute. According to the Army, the only way to achieve the required rate of fire is to use an artillery system equipped with autoloader and automatic fuze-setting capabilities. Army officials did not provide any documentation showing that an autoset capability would be a part of the Advanced Field Artillery System. Therefore, there is no assurance

that the Army has made a commitment to develop an artillery system that can use the automatic fuze-setting capability.

Faster, Easier, and More Accurate Settings

The Army stated that testing has demonstrated that the M762 electronic time fuze can be set faster, more easily, and more accurately than the M577 mechanical fuze. Tests conducted in temperate, arctic, and nuclear, biological, and chemical environments showed that the electronic fuze has a clear advantage over the mechanical fuze in the time it takes to set for long-range firing. The mechanical fuze, however, was set faster and easier than the electronic fuze for short-range firings and for medium-range firings in arctic and nuclear, biological, and chemical environments. Table II.1 summarizes the results of the tests.

Table II.1: Mean Time in Seconds to Set
Fuzes

Time in Seconds		
Range	M577	M762
Temperate climate		
Short	9.3	10.5
Medium	16.1	11.6
Long	33.6	16.5
Arctic/nuclear, biological, and chemical		
Short	12.0	18.8
Medium	28.7	29.8
Long	56.2	36.3

The Army said that fewer setting errors occurred with M762 fuzes. In August 1987, the Army's Human Engineering Laboratory evaluated the two fuzes for setting errors. The evaluation disclosed that test participants set the M762 electronic fuze more accurately under both temperate and arctic conditions but that the number of large errors was about the same for both fuzes. The test participants performed 96 settings on each type of fuze. They made 10 setting errors on the M762 electronic fuze and 16 setting errors on the M577 mechanical fuze. Table II.2 shows the frequency and magnitude of errors for the two fuzes. Errors are measured in terms of the number of seconds between accurate and erroneous setting times.

Appendix II
Advantages and Disadvantages of the
Electronic and Mechanical Fuzes

Table II.2: Frequency and Magnitude of
Fuze-Setting Errors

Magnitude of errors (seconds)	M577	M762	Total
Small errors			
0.1	5	2	7
0.2	5	2	7
0.3	0	1	1
0.4	2	0	2
Total	12	5	17
Large errors			
2.0	1	0	1
3.3	0	1	1
4.8	0	1	1
7.6	1	0	1
10.0	2	1	3
90.0	0	1	1
100.0	0	1	1
Total	4	5	9
Total	16	10	26

Greater Time-Setting Accuracy

According to the Army, the M762 electronic fuze can be set with greater accuracy than the M577 mechanical fuze. However, we found that this greater time-setting accuracy does not provide greater effectiveness. The Army Materiel Systems Analysis Activity (AMSAA) stated in its Independent Evaluation Report on the M762 electronic fuze that, on the basis of test results and the inherent design features of the M762 electronic fuze, it can be argued that the electronic fuze demonstrates perfect timing precision. Even so, AMSAA studies have repeatedly shown that increased timing accuracy does not mean increased effectiveness. In addition, according to AMSAA, variations in other artillery-firing factors, such as muzzle velocity, ballistic coefficient, and projectile launch angle, affect accuracy much more than variations in fuze-timing accuracy.

Larger Production Base

The Army stated that a greater number of contractors will compete to produce M762 electronic time fuzes, resulting in a larger production base for the M762 than for the M577 mechanical time fuze. In terms of number of bidders, this is apparently the case. Only 2 contractors submitted bids for the fiscal year 1989 M577 mechanical time fuze procurement, while 11 contractors submitted bids for the M762 electronic fuze.

While the number of current producers is limited, Army production information indicates that two mechanical fuze producers—Hamilton Technology, Incorporated, and Bulova Systems and Instruments Corporation—are capable of producing one million M577 mechanical fuzes annually, operating a single 8-hour shift, 5-days per week.¹ Since the M762 electronic time fuze has never been mass-produced, no such production information is available. AMSAA, in its role as independent evaluator, stated that the M762, as a state-of-the-art fuze, will undoubtedly require specialized facilities to produce. AMSAA recognized that there are problems in producing the M577 mechanical fuze but also stated that it is becoming more producible. For example, the number of mechanical parts has decreased, and production is becoming more automated. AMSAA also stated that the problems involved in producing the M762 electronic time fuze are as yet unknown.

AMSAA officials stated that current procurement regulations allow for increased cost if the purpose is to broaden the production base of an existing commodity. Therefore, they believe that it may be more practical to broaden the production base of the M577 mechanical time fuze by encouraging more vendors to participate in producing the M577 mechanical time fuze than to establish production lines for the M762 electronic time fuze.

Interoperability With North Atlantic Treaty Organization Systems

The Army said that the M762 electronic fuze is compatible, or “interoperable,” with NATO artillery systems. However, the M577 mechanical time fuze can also be used in NATO artillery systems. Currently, NATO countries are buying the M577 fuze from Hamilton Technology, Incorporated, through the NATO Material Supply Agency. On the basis of a NATO Fuze Committee review of the paperwork pertaining to the electronic fuze subsequent to its type classification, the Army believes that the electronic fuze meets the interoperability requirement. However, tests are required to confirm its interoperability, and these tests are not scheduled to be conducted until production qualification testing of the initial fiscal year 1989 production quantity of M762 electronic fuzes.

¹During the course of our review, Bulova purchased all of the outstanding shares of Hamilton, and Hamilton is now a wholly owned subsidiary of Bulova.

State-of-the-Art Technology

The Army said that the M762 electronic time fuze uses integrated circuitry similar to what is used in a digital watch. This state-of-the-art technology is different from the M577 fuze's mechanical timing mechanism, which is similar to what is used in an analog watch. However, according to AMSAA, the M762's state-of-the-art technology does not provide any significant improvement in tactical operational effectiveness.

Other Issues Associated With the Electronic and Mechanical Fuzes

In a March 2, 1989, letter to a Member of the Congress, the Assistant Secretary of the Army (Research, Development and Acquisition) cited an additional benefit of replacing the M577 fuze with the M762 electronic time fuze: a reduction in the number of fuzes in the Army's inventory. However, we found that the number of different fuzes in the Army's inventory would in fact remain the same, since the older fuzes would not become obsolete for at least 20 years.

In addition, during our review we obtained information on a reliability problem with the M577 mechanical time fuze and actions being taken to address an early detonation problem experienced by the M762 electronic time fuze. We have included this information because it could be useful to the Committees on Appropriations as they consider the Army's procurement plans for electronic time fuzes.

Reducing the Number of Different Fuzes in the Army's Inventory

The Assistant Secretary said that the M762 and M767 electronic time fuzes are scheduled to replace M564, M565, M577, and M582 mechanical time fuzes. However, the Army plans to retain its inventory of these older mechanical fuzes as long as they continue to be safe and reliable. According to AMSAA, historically, new fuze developments have increased rather than decreased the number of different types of fuzes in the Army's inventory. Since the M762 electronic time fuze is ballistically matched to the M577 mechanical time fuze, both fuzes are capable of performing essentially the same functions. When artillery weapon systems are provided an autoset capability, the mechanical fuzes will not immediately become obsolete. AMSAA's position is that it normally takes approximately 20 years for a new technology to become the predominantly fielded system.

Reliability of the Fuzes

The M577 mechanical time fuze and the M762 electronic time fuze both function in the timed and point-detonating modes. Their function reliability requirement is the same: they must function 96 percent of the time. Both fuzes have demonstrated better than 96-percent function reliability. The M762 electronic fuze demonstrated better performance at the temperature ranges of minus 25 degrees Fahrenheit to 110 degrees Fahrenheit, while the mechanical fuze functioned better at temperatures below minus 25 degrees Fahrenheit and above 110 degrees Fahrenheit.

Surveillance tests of prepositioned stocks disclosed the substandard reliability of some Hamilton-manufactured M577 mechanical time fuzes. As a result of these tests, 890,000 M577 fuzes were suspended from tactical

use. An Army official stated that the problem with the fuze's reliability surfaced in 1986 when a Hamilton fuze lot was tested for reliability. These fuzes had been stored on a prepositioned ship in the Indian Ocean for 2 years.

The Army determined that insufficient lubrication at the time of manufacture, coupled with storage conditions aboard the ship, had dried out the oil in the timer module of the fuzes. Since the discovery of the lubrication problem, the Army has changed the M577 fuze drawings to specify the exact lubrication procedure and testing to be used by the contractor when assembling the fuze. The M577 mechanical fuzes produced by Bulova do not have this problem. The suspended fuzes will function when set for times up to 30 seconds or when they hit the ground. That is, they can be used for short time settings or in the point-detonating mode. Since the defective M577 fuzes can still be used, the Army is converting 323,000 of them to M582 fuzes for training. The remaining 567,000 defective fuzes can be restored by lubricating the timer modules in accordance with the new lubrication procedure.

Unresolved Safety Problem With the M762 Electronic Time Fuze

The M762 electronic time fuze experienced a major problem during developmental testing. On 17 occasions, it detonated prematurely when used with artillery rounds being fired in mostly cloudy weather. After investigating the failures, the Army concluded that an electrostatic discharge had upset the fuzing circuits, causing the detonator to function early. This problem was most evident when the fuzes were subjected to high temperatures (145 degrees Fahrenheit and above), high velocity (over 2,600 feet per second), and were fired into heavy cloud cover where static conditions were greater. Motorola, Inc., developed a three-piece aluminum shield to fit around the printed wiring assembly, providing it with protection from electrostatic discharge. According to the Army, this shield has resolved the problem with premature detonation. The Army reached this conclusion on the basis of laboratory testing and 21 successful test firings: 15 in the point-detonating mode and 6 in the time mode.

Although all 21 test firings were successful, AMSAA raised concerns that the limited testing of the new shield had not been corroborated with required safety testing (i.e., all of the safety testing had been done on the pre-shield design). Although the shielded design might have eliminated the problem with electrostatic discharge, AMSAA does not consider the laboratory tests and the 21 in-flight tests of shield fuzes as sufficient to satisfy the safety requirements for safe flight qualification. Safety

Appendix III
Other Issues Associated With the Electronic
and Mechanical Fuzes

testing will not be performed until production qualification testing because the Army ran out of development funds for the electronic fuze. AMSAA's test plan requires 384 fuzes for safety confirmation testing, which will include the testing of 52 fuzes for insensitivity to electrostatic discharge.

Objectives, Scope, and Methodology

As requested in the Conference Committee report on Department of Defense appropriations for fiscal year 1989 (House Report 100-1002, Sept. 28, 1988) and as agreed in subsequent discussions with the requesters, we reviewed data supporting the Army's decision to type classify the M762 electronic time fuze and the cost and benefits of the electronic time fuze as compared to the cost and benefits of the existing mechanical time fuze. In May 1989, we reported on the type classification of the M762 electronic time fuze. This report addresses the cost and benefits of the electronic and mechanical fuzes.

In conducting our review, we examined (1) the Army's current and projected cost estimates for the electronic and mechanical fuzes, (2) the Army's life-cycle cost estimates for the electronic fuze to determine if and when it would reach cost comparability with the mechanical fuzes, (3) the Army's procurement plans for mechanical and electronic time fuzes, and (4) the Army's data on the capabilities and performance of the electronic and mechanical fuzes to determine their benefits.

We performed our work from November 1988 to August 1989 in accordance with generally accepted government auditing standards. As requested, we did not obtain official agency comments on this report. However, we discussed the results of our analysis with officials from the Office of the Secretary of Defense and the Department of the Army and have incorporated their comments where appropriate.

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